A MOUNTED SKELETON OF DIMETRODON GIGAS IN THE UNITED STATES NATIONAL MUSEUM, WITH NOTES ON THE SKELETAL ANATOMY.

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INTRODUCTION.

During the spring of 1917 the United States National Museum acquired from Mr. C. H. Sternberg, a small collection of vertebrate fossils, which he and his son Levi had made earlier in the season from the Permian formation as exposed in the vicinity of Seymour, Baylor County, Texas.

The collection consists of a very fine skeleton of *Dimetrodon gigas* Cope, several hundred bones of the smaller species of *Dimetrodon*, and between 35 and 40 skulls and partial skeletons of the smaller reptilian and batrachian forms that comprise this interesting fauna.

The greater part of the collection was obtained from a deposit of bones on the Craddock ranch, discovered in 1909 by members of an expedition from the University of Chicago. In writing of this discovery, Doctor Williston [1] designated it as the "Craddock Bone Bed," and I quote below from his remarks on the manner of occurrence of the fossils found there.

> The bones in this deposit extend through a thickness of about 1 foot over a considerable space, a few hundred square feet, imbedded in red clay like that of the Cacops bed. They are unlike those of the Cacops bed, however, for the most part isolated and generally more or less free from incrusting matrix, and usually in the most perfect preservation. Not a few, however, show effects of erosion, as though they had been rolled upon a beach of hard, shallow bottom.

The skeleton of *Dimetrodon gigas*, as so often happens in deposits of fossil bones, was the one exception to the general conditions prevailing there in that considerable portions of the skeleton were found articulated, and the association of these articulated and other parts as pertaining to a single individual was further indicated by an adhering matrix which cemented them together into compact masses. For example, the skull was found disarticulated, but its separate elements with the jaws were bound into one mass by the enclosing

[1] Williston, S. W., American Permian Vertebrates, pp. 5-7, 1911.

matrix. The articulated left fore limb and foot was attached by matrix to the string of anterior dorsal vertebrae, and to a mass of thoracic ribs. Some few of the posterior vertebrae were found isolated but not far removed from the articulated series.

This specimen No. 8635, U.S.N.M., as finally assembled has the following bones present: Greater portion of skull; both rami of the lower jaws; representative parts of each of the complete presacral series of 27 vertebrae; first caudal; several complete and parts of most of the other ribs of both sides; left scapula, coracoid, procoracoid, and clavicle; left humerus, radius, ulna, and foot; left femur and tibia. The vertebrae except for the loss of four centra in the anterior dorsal region are quite perfectly preserved.

The sacrum has been supplied from a second individual, No. 8661, U.S.N.M., from the same deposit and of slightly smaller proportions. The pelvic bones and the interclavicle were kindly furnished by the late Dr. S. W. Williston from the collections of the Walker Museum. The right pelvic bones have the catalogue No. 8658, U.S.N.M.; the left is No. 8657, U.S.N.M.; the interclavicle bears the No. 8656, U.S.N.M., being the bone figured by Case in his Pelycosauria of North America (pl. 15, fig. 4). The other missing parts have been restored in plaster and painted a distinctive color.

The bones were so free from distortion that it was decided to make an open mount of the skeleton, though the difficulties of doing so were well understood. The unusual mechanical problems embodied in the mounting of a skeleton of such fragile proportions were skillfully overcome by Mr. T. J. Horne, preparator in the Section of Vertebrate Paleontology of the United States National Museum who mounted the specimen. It is the first attempt to reconstruct a free mount of an entire skeleton of a *Dimetrodon*, and the success of the undertaking may be best judged by an examination of the photographic reproduction of the skeleton here shown in Plate 70.

The pose of the skeleton was adopted after a study of living lizards and is an attitude often assumed by those land forms of the present day. The opening of the jaws to better display the rows of bristling teeth gives the animal an appearance of angrily defying one who has suddenly blocked his path.

The specimen is standing on an artificial base colored in imitation of the red clay in which the bones were originally embedded.

The total length of the skeleton from the tip of the nose to the end of the tail, between perpendiculars, is 6 feet 9 inches. From the base level to the top of the highest spine it measures 4 feet 9½ inches. Although *Dimetrodon gigas* is the largest species of the genus, the present individual is a moderate-sized representative of that species.

In plate 73 is shown a model restoration of this animal prepared by the writer and which expresses his conception of its appearance in life.

The one most striking feature of *Dimetrodon* is the high dorsal fin-like crest along the median line of the back formed by the elongation of the neural spines of the vertebrae. That in life these tall spinous processes were united by a thin membrane of skin there is little doubt, though Professors Abel and Jaekal are disposed to think the spines were covered by skin but not connected. The one living lizard which throws some light on this problem is *Basiliscus plumifrons* from tropical America (see inset plate 73), which has the crest on the back; though not so high or extensive as in *Dimetrodon,* is nevertheless supported by the elongated spinous processes of the vertebrae, and in it we have the best suggestion of the probable appearance in life of the crest in *Dimetrodon.*

In trying to account for some practical use for this unusual outgrowth, it has been suggested that it may have resembled some of the ancient vegetation, and thus served to conceal the animal as it lay in wait for its prey or for better concealment from its enemies. Prof. E. C. Case says of these:[1]

> The elongate spines were useless, so far as I can imagine, and I have been puzzling over them for several years. * * * It is impossible to conceive of them as useful either for defense or concealment, or in any other way than as a great burden to the creatures that bore them. They must have been a nuisance in getting through the vegetation, and a great drain upon the creatures vitality, both to develop them and keep them in repair.

The head of *Dimetrodon* is enormously large in proportion to the size of the body. The jaws are provided with powerful incisor and maxillary tusks, the largest of which reach a length of 3 inches. The cheek teeth are recurved, with sharp, serrate edges. There is no animal known which has a more efficient apparatus for the capture of its prey. The eyes were large and set well back and high in the head. The neck is short, the limbs are strong, having feet with 5 digits, each of which is terminated by a sharp claw. No specimen has as yet been found with a complete tail, but the rapid decrease in size of the known caudal vertebrae suggests a short tail, and it has been so restored in the mounted skeleton. The specimen here pictured in plate 70, although a representative of the largest species of the genus, is exceeded in size by several known individuals. The presence of the greater number of the ribs of both sides shows the great depth of the body cavity and the extreme flatness of the sides of the anterior part of the body. From a study of the habits of living reptiles it is known that those with compressed bodies are usually dwellers among bushes and trees. Professor Case is of the opinion that *Dimetrodon* is descended from an aquatic ancestry, and that it ranged widely over the land. It is probable that ordinarily the animal did

[1] The Permo-Carboniferous, Beds of North America and Their Vertebrate Fauna. Pub. No. 207 Carnegie Institution, Washington, 1915, p. 142.

not raise his body far above the ground, but crawled around much after the fashion of the crocodile, though, quoting again from the above author:

> The strong limbs with longer foreleg than upper leg, with strong feet, with powerful claws, ample evidence of an ability to run with some speed and perhaps even leap or pounce upon prey. Abel, in his Paleobiologie, points out that running and leaping animals have the foreleg longer than the upper leg, and creeping animals have the proportions reversed. It is not probable the *Dimetrodon* was ever capable of leaping any distance, but it certainly was able to move swiftly for a short space. Probably it lay hidden in the vegetation, and made short, scuttling rushes upon its prey, ending, possibly, with a short pounce, which permitted its weight to add something to the vigor of the attack by tooth and claw.

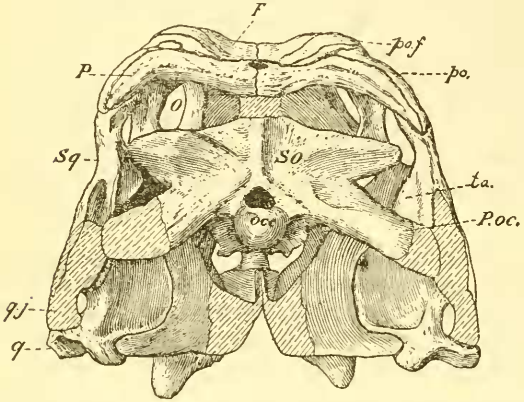

Fig. 1.—Dimetrodon gigas, posterior aspect of skull. No. 8635 U.S.N.M. One-fourth natural size. *F.*, frontal; *o.*, orbit; *occ.*, occipital condyle; *P.*, parietal; *po.*, postorbital; *P. oc.*, paraoccipital; *po. f.*, postfrontal; *q.*, quadrate; *q. j.*, quadratojugal: *So.*, supraoccipital; *Sq.*, squamosal; *ta.*, doubtful articulation for the tabulare.

Dimetrodon was the dominant and probably the most formidable animal of his time. Of the contemporary animals of the Permian there was a vast assemblage of reptiles and amphibians, and it was these that the cruel jaws were peculiarly adapted for catching. The borders of pools and swampy places were probably the regions most densely populated by these lesser forms, and no doubt such places were the favorite haunts of the *Dimetrodon.*

NOTES ON THE SKELETAL STRUCTURE OF DIMETRODON GIGAS COPE

Skull.—Through the studies of Baur, Case, Williston, Broom, and von Huene, the structure of the skull of *Dimetrodon* is now pretty well known. There is still divergence of opinion regarding the extent of the boundaries of some few of its elements, and of the homologies of certain others. At this time it is the composition and extent of the bones forming the posterior part of the cranium that appears to be least understood, and while the skull of No. 8635, U.S.N.M., offers but little positive information for making clearer our understanding of the occipital region, it does offer suggestions which may eventually be of help in arriving at the correct interpretation of these parts.

The median bones of the occipital region were found articulated as shown in figure 1. The sutures are entirely obliterated—a condition found to prevail in four other individuals in this same collection. All authorities, I think, are now agreed that this part of the occiput consists of a median supraoccipital, small exoccipitals, large paraoccipitals (opisthotics), and basioccipital. In addition to these Huene in 1913 [1] recognized a distinct dermosupraoccipital (postparietal) bone lying between the upper extremity of the supraoccipital and the parietal, and laterally a tabulare and supratemporal bones.

In assembling the bones of the present skull all of those preserved could be articulated except the one illustrated in figure 2. It was submitted to Dr. S. W. Williston, who identified it as being a portion of the tabulare and dermosupraoccipital, but I have not been able to satisfactorily articulate these bones, so they have been left off the skull until such time as their proper place shall be definitely determined.

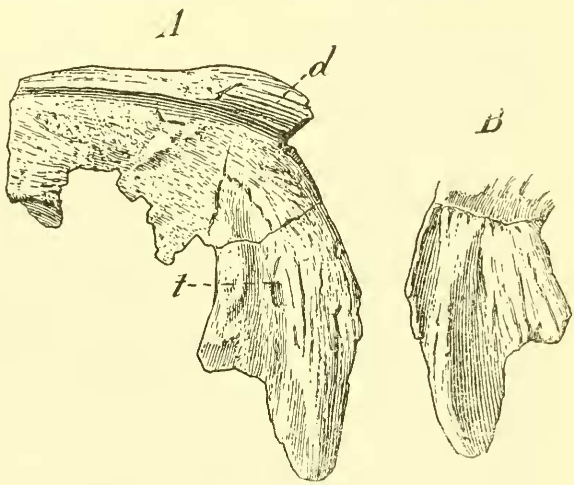

Fig. 2.—Dimetrodon gigas occipital bones No. 8635, U.S.N.M. ¾ natural size. *A*, external aspect. *d*, dermosupraoccipital; *t.*, tabulare. *B*, internal aspect of concave articular surface of tabulare.

The squamosal shows on its medial side a convex triangular articular facet (see fig. 1, *ta*), which I first regarded as the surface for articulation with the concave area of the so-called tabulare shown in B, figure 2. These two surfaces seem to be counterparts, but unfortunately the tabulare appears to belong to the right side, while the one squamosal present pertains to the left side of the skull, so that a direct trial could not be made. Furthermore, I have never been able to orientate the bones shown in figure 2, so that their relationships with the other elements of the posterior aspect would be entirely in harmony. Another suggestion as to the use of this articular facet on the squamosal, arrived at since the skull was articulated, is that it may be for the paraoccipital process. In the event of that fact being established it would necessitate the shifting upward of the whole central mass of the occiput to a higher position. Such a change would bring the supraoccipital in contact on the ventral side with the

[1] Bull. Amer. Mus. Nat. Hist., vol. 32, 1913, p. 359, fig. 44.

parietals, as it is usually, if not always, found in the reptilia. The median superior border of the supraoccipital is not united by suture with the overlying parietals, but presents a finished grooved border for cartilagenous attachment—a condition found in many of the Predentate dinosauria.

The presence of such a border casts grave doubt on the authenticity of Huene's determination, where he depicts [1] the supraoccipital as attached by jagged suture with a dermosupraoccipital that is interposed between it and the parietals. Either the upper median portion of these coalesced occipital bones in No. 8635, U.S.N.M. (fig. 1) represent the dermosupraoccipital or else Huene's interpretation is in error. All the evidence sustains the latter conclusion, but as to how the dermosupraoccipital does articulate with the parietals the present specimen offers no evidence.

The complete, uncrushed left squamosal is present, and it appears to clear up some of the earlier determinations of authors. The upper end is obliquely truncated, presenting on the superior surface of the upper end an articular face, the outer half of which is certainly for articulation with the posterior branch of the postorbital; the inner half of this facet meets the outer end of the parietal. It should be stated, however, that the parietal was found detached, but everything about it appeared to indicate a close union with the posterior branch of the postorbital and squamosal as shown in figure 1.

There was no evidence of the separation of the posterior extremities of these bones by an interposed supratemporal bone such as found by Huene, and I think it highly improbable that such a condition existed, for were the supratemporal present in this position in *Dimetrodon*, contact between the parietal and squamosal would be severed—a most unusual condition in the reptilia.

Broom in his restoration [2] of the skull of *Dimetrodon* shows the parietal and postorbital in close apposition and both properly in contact with the squamosal. In view of the evidence now before me I can see no possibility of there being an element thrust in between the posterior extremities of these bones such as found by von Huene.

The quadratojugal is another bone whose limitations are not as yet fully and satisfactorily determined. This bone is represented in the present skull by the greater portion of the left element. It had not been identified at the time of articulating the skull, so does not appear in the illustrations. As preserved it is a small irregularly shaped bone, with a short lateral process which extended forward to overlap the posterior end of the jugal (see fig. 1, *qj.*) and a superior process which extended upward behind the quadrate to unite with the squamosal as shown in figure 1. Huene has correctly viewed the lateral extent of the quadratojugal (fig. 42, p. 357), but he appears to have been in error regarding its superior process, which he con-

[1] Bull. Amer. Mus. Nat. Hist., vol. 32, 1913, p. 359, fig. 44 A.

[2] Broom, R. Bull. Amer. Mus. Nat. Hist., vol. 28, 1910, p. 225, fig. 19.

sidered short. This process has been broken off and is missing from specimen No. 8635, U.S.N.M., but is shown restored in its entirety on the right side of the posterior aspect of the skull in figure 1. The upper extremity on the left side was purposely left out so that the artist could depict the decided depression on the posterior border of the squamosal.

If this articular depression is not for the reception of the upper end of a process from the quadratojugal, I am utterly at loss to know its function. That other specimens have obscurely indicated such an extension of this process is shown in a figure[1] of the posterior aspect of a *Dimetrodon* skull illustrated by Case, where the left element is shown extending up as high as the paraoccipital process.

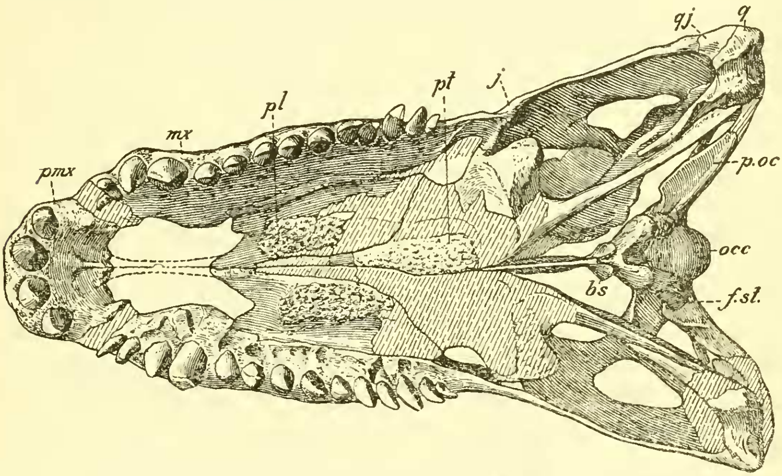

FIG. 3.—SKULL OF DIMETRODON GIGAS COPE, NO. 8635, U.S.N.M. PALATAL VIEW. ONE-FOURTH NATURAL SIZE. *bs*, BASISPHENOID; *f. st.*, FACET WITH WHICH THE STAPES ARTICULATED; *j*, JUGAL; *mx*, MAXILLARY; *occ.* OCCIPITAL CONDYLE; *pl.*, PALATINE; *pmx*, PREMAXILLARY; *p. oc.*, PARAOCCIPITAL PROCESS; *pt.*, PTERYGOID; *q.*, QUADRATE; *qj.*, QUADRATOJUGAL.

The union of the quadratojugal and quadrate on the ventral border is by an inverted V-shaped notch on the distal side of the former which fits over the outward extension of the articular portion of the latter. Immediately above this notch on the medial side is the rounded border forming the outer boundary to the foramen between these two bones.

The bones of the top of the skull are pretty well known, and the skull as restored agrees quite closely with the determinations of Case and other authorities. The septo-maxillaries are present, being found attached by matrix to the posterior end of the premaxillary. These were displaced in relation to one another, and I have been unable to articulate them with any degree of confidence of their being correctly placed.

In figure 3, I present a view of the palate of No. 8635, U.S.N.M., which in the main agrees closely with Broom's restoration of this

[1] Bull. Amer. Mus. Nat. History, vol. 28, 1910, p. 193, fig. 4.

aspect of the skull differing chiefly in the proportions of some of its elements. The anterior portion of the palatines are relatively wider than represented by Broom, and the pterygoids, especially their anterior prolongation, is clearly shown by this specimen to be narrower than in any restoration yet given. It now appears quite probable that in articulating this skull the palate especially between the maxillaries has been made too narrow, thus closing up the posterior median aperture.

Vertebral column.—The complete backbone in front of the sacrum in *Dimetrodon*, according to Dr. E. C. Case, consists of 27 vertebrae. In the present specimen there were parts present of that number of presacrals. The atlas was represented only by the preatlantal intercentrum, and vertebrae 11, 13, 14, and 15 (counting from the head backward) by their spinous processes. The other vertebrae of the series are unusually well preserved, but all except the fourth and sixth lack the proximal terminations of the spines. In articulating the skeleton the fourteenth and fifteenth have been assigned centra that were found associated with this specimen, but there is no evidence to show that they belong to these particular vertebrae. There is a single caudal present that on account of the large size of its transverse processes is called the first of the series. The missing sacral vertebrae have been supplied from a second individual (No. 8661, U.S.N.M.), belonging to the same collection and from the same deposit of fossils. It appears to pertain to a slightly smaller individual than No. 8635, U.S.N.M. With the exception of the single caudal mentioned above the remainder of the tail has been restored.

The fin-like crest along the back formed by the lengthened spinous processes of the vertebrae presents a notably different aspect than found in the previously mounted skeletons of *Dimetrodon incisivus*, but whether the differences observed represent constant features peculiar to *Dimetrodon gigas*, I am not prepared to decide at this time. Unlike *D. incisivus*, where the spines rise perpendicularly and rapidly lengthen from the axis backward, the first four posterior to that bone in this specimen are of about equal height. Beginning with the seventh of the series they rapidly grow longer as we proceed posteriorly in the column, reaching their maximum development with the twelfth vertebrae. Continuing posteriorly they gradually diminish in length, finally graduating into the short spines of the tail. The processes of the first dorsals have a tendency to rise vertically, but as we pass backward they assume an oblique and finally a curved retroverted position overhanging the sacrum.

The spinous process on the fourth cervical is complete, being terminated by a cupped extremity. It measures 220 mm. in length from center of neural canal to tip. The sixth spine is very nearly perfect, lacking only a small portion of the tip. All of the others have suffered more or less loss from their upper ends, but none show any expansion of this end as in *Edaphosaurus;* all probably tapered to a pointed end with cupped extremity.

Several of the spines as shown in plate 71 have large exostoses showing that they have been broken and healed during life.

Ribs.—Parts of nearly all the ribs are present, of which six are complete. None were found articulated, so that their present position in the skeleton is based entirely on a study of their relative size, spread of head between capitulum and tuberculum as compared with the vertebral articulating facets. Counting back from the axis, ribs Nos. 7, 9, 10, and 11 of the right side, and Nos. 7 and 16 of the left side are perfectly preserved.

The anterior thoracic ribs when articulated form a much flattened and exceedingly deep body cavity immediately behind the fore-legs. (See pl. 72, fig. 1.) More posteriorly, however, the ribs take on a decided convexity, as may be seen by comparing ribs *A* and *B*, figure 4. All of the thoracic ribs are terminated distally by slightly expanded cylindrical ends that are cupped for the better attachment of the cartilagenous ribs of the belly.

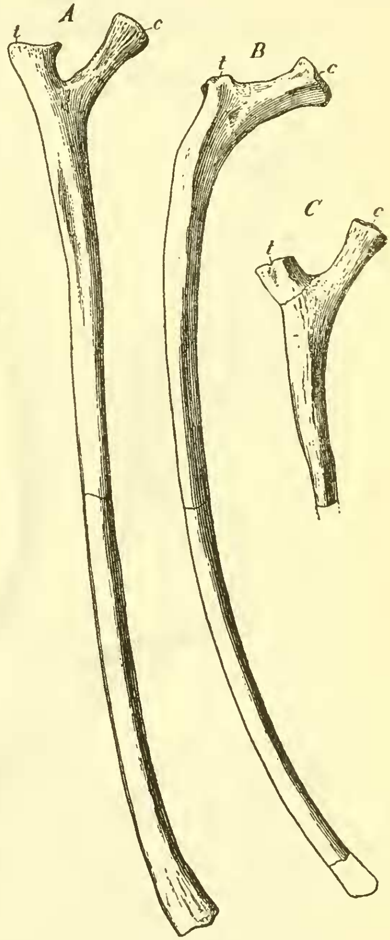

Fig. 4.—Ribs of Dimetrodon gigas, No. 8635, U.S.N.M. *A*, seventh rib of right side, viewed from the front; *B*, sixteenth rib of left side, (reversed) viewed from front; *C*, median cervical rib; *c*, capitulum; *t*., tuberculum. All figures about one-third natural size.

There was no evidence of the presence of ossified abdominal ribs. The seventh pair of ribs, the longest of the entire series, measure 395 mm. in length. The sixteenth rib of the left side is 334 mm. long measured from the tuberculum over the curve.

Shoulder girdle and fore limb.—In his monographic work, "The Pelycosauria of North America,"[1] page 121, Case says: "The shoulder girdle of *Dimetrodon gigas* unknown." It is, therefore, of interest to find with specimen No. 8635, U.S.N.M., the complete

[1] Pub. 55, Carnegie Institution of Washington, 1907.

left half of this girdle articulated with the almost perfect limb and foot. (See pl. 72, fig. 2.)

I have carefully compared these bones with the homologous elements of the smaller and better known species, *Dimetrodon incisivus*, but, except for their larger size, fail to detect differences which might be of help in distinguishing them specifically.

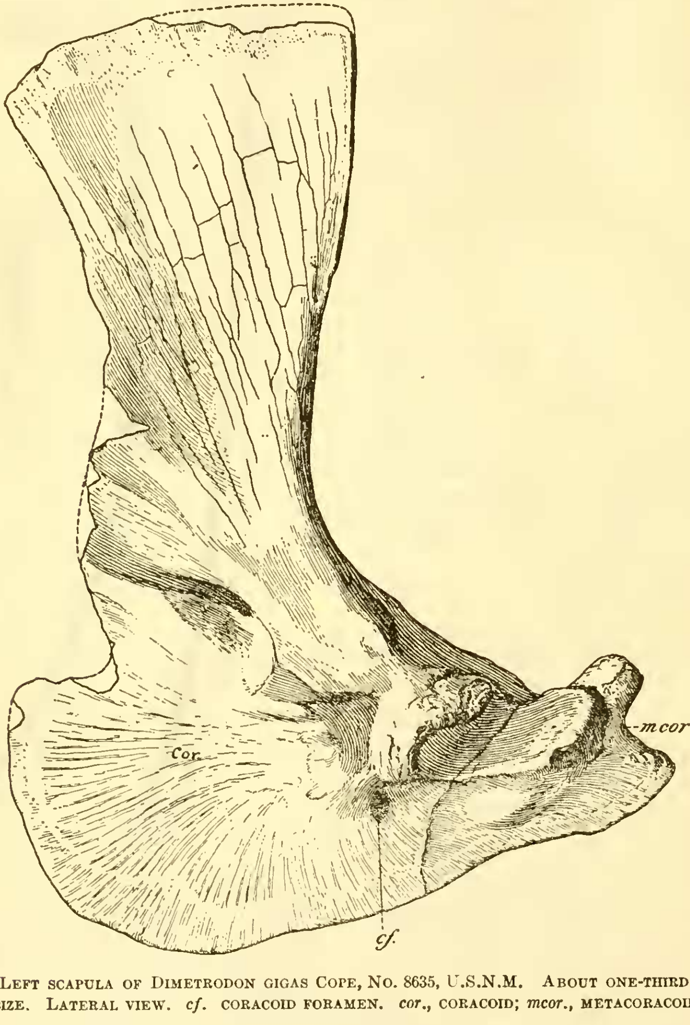

FIG. 5.—LEFT SCAPULA OF DIMETRODON GIGAS COPE, NO. 8635, U.S.N.M. ABOUT ONE-THIRD NATURAL SIZE. LATERAL VIEW. *cf.* CORACOID FORAMEN. *cor.*, CORACOID; *mcor.*, METACORACOID.

Scapula.—The unusually well-preserved left scapula coossified with the coracoid and metacoracoid is known in figure 5.

The suture defining the junction of scapula and coracoid has been entirely obliterated, but between the coracoid and metacoracoid it remains distinct as shown in figure 5.

From end to end there is a decided convex curvature which conforms well to the form of the body and also throws the expanded coracoid end somewhat inward to form the chest. The greatest length of these coossified bones is 410 mm. measured over the curve. Greatest expanse of distal end, 235 mm.; of proximal end, 140 mm.

No cleithrum has been restored in the mounted skeleton as no bones which could be referred to this element were found in the collection.

The humerus of *Dimetrodon gigas* can only be distinguished from *D. incisivus* by its much larger size. Case [1] observes that in the humerus of the type of *D. gigas* "differs from *Dimetrodon incisivus* in the articular face, which involves the whole of the proximal end, and the radial crest, which, while being strong is not long, beginning lower down on the head and not continuing so far distally.

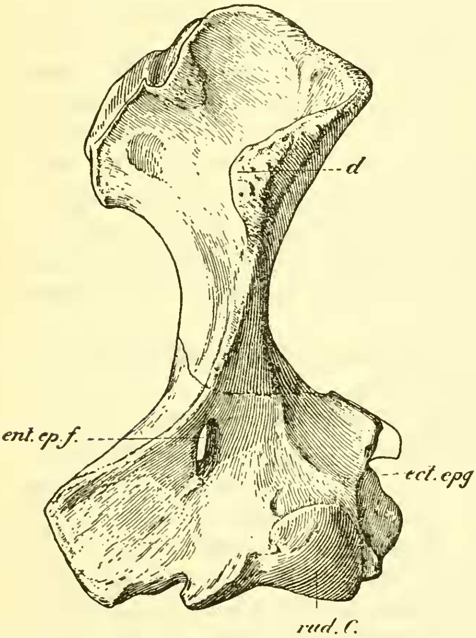

Fig. 6.—Left humerus of Dimetrodon gigas Cope, No. 8635, U.S.N.M. One-third natural size. Anterior or ventral view. *d.*, radial or deltoid crest; *ect. epg.*, ectepiconylar notch; *ent. ep. f.*, entepicondylar foramen; *rad. C.*, radial condyle.

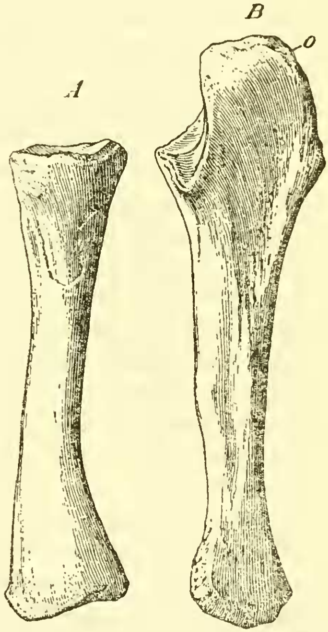

Fig. 7.—Left radius and ulna of Dimetrodon gigas Cope., No. 8635 U.S.N.M. *A.* Radius viewed from the front. *B.* Ulna viewed from the front. *o.*, olecranon process. Both figures one-third natural size.

The edges of the proximal end are quite rugose." I fail to observe any such differences. There are 16 *Dimetrodon* humeri, large and small, in the United States National Museum collection, and though they were found to differ in some minor details all were essentially alike.

The greatest length of the present humerus is 235 mm.; greatest width of the proximal end 128 mm.; greatest width of distal end 136 mm.; least diameter of shaft 29 mm.

The *radius* and *ulna* have also been carefully compared and as with the humerus, their larger size is the chief difference found. The principal features of these bones are shown in figures 6 and 7.

[1] Publication No. 207, Carnegie Institution, Washington, 1915, p. 121.

The ulna has a greatest length of 236 mm.; greatest diameter of proximal end, 68 mm.; greatest diameter distal end, 41 mm.

The radius has a length of 190 mm.; greatest diameter proximal end, 50 mm.; greatest diameter distal end, 48 mm.

According to Case the femur of *Dimetrodon gigas* has a heavier outer condyle and a slightly curved shaft, which distinguishes it from *D. incisivus*. I fail to note any difference except that of size in the femur of No. 8635, U.S.N.M., when compared with femora of *D. incisivus*. The femur has a greatest length of 240 mm.; greatest width of distal end, 90 mm.; of proximal end, 79 mm.; the least width of shaft, 26 mm.

Like the femur the tibia shows no characters peculiar to this species. The greatest length of the tibia is 195 mm.

Carpus and forefoot.—The left forefoot of specimen No. 8635, U.S.N.M., appears to be the most complete manus of a *Dimetrodon* that has yet been discovered, and the first to be described of the species *D. gigas*. Fortunately the greater number of the bones comprising it were found articulated, thus giving positive evidence of their proper association and arrangement as shown in figure 8.

Case,[1] it appears, was the first to figure and describe the articulated carpus and portions of attached metacarpus of this genus, based on a *D. incisivus* foot.

In 1911 Williston [2] published a figure of an articulated carpus of this same species giving an anterior view.

These references cover practically all that has been written on the feet of *Dimetrodon*. The hind feet are as yet practically unknown.

The carpus in the present specimen is complete except for the element designated by Case the ''sesamoid,'' which articulates with well-defined facts on the radiale side of centrale 2 and carpale 1. It has been restored here (see *s*, fig. 8) after an element belonging with a forefoot of *D. incisivus* kindly loaned me by Dr. S. W. Williston. Metacarpals 3, 4, and 5 and proximal phalangials 1 and 2 of digits 4 and 5 were found articulated or so little displaced as to raise no doubt as to their being in proper sequence. Other bones that were detached but found associated in the same field packages were metacarpal 1, proximal phalangials of digits 1, 2, and 3, and two ungual phalanges, here arbitrarily placed on digits 4 and 5. (See fig. 8.) All of these detached elements probably pertain to this foot, but of phalangial 2 of digit 2 and coossified phalangials 2 and 3 of digit 3, and the unguals of the first three digits, one can not be so sure they pertain to this same individual. However, the final test of the correctness or incorrectness of the association of these elements as

[1] Case, E C. Journ. of Geology, vol. 11, No. 1, p. 11, 1903, and Pelycosauria of North America, Carnegie Institution, Pub. No. 55, 1907, pp. 113–114, pl. 16, fig. 1.

[2] Williston, S W. American Permian Vertebrates, 1911, pl. 7, fig. 8.

illustrated in figure 8 must await the discovery of a more complete articulated manus.

The carpus of *Dimetrodon* as known at this time consists of 11 elements, though Williston is of the opinion that a pisiform[1] will be found articulating in the interval between the ulna and ulnare, as in modern reptiles and as it does in *Varanosaurus, Casea, Limnosceles*, and *Trispondylus*.

The proximal row consists of three bones (the radiale, intermedium, and ulnare), a median row of two centrale, and a distal row of five carpale. These carpal bones articulate with one another by well-defined facets and with the metacarpals by equally well-developed articular faces, which indicate clearly the spreading nature of the digits and especially the decided divergence of digit 5.

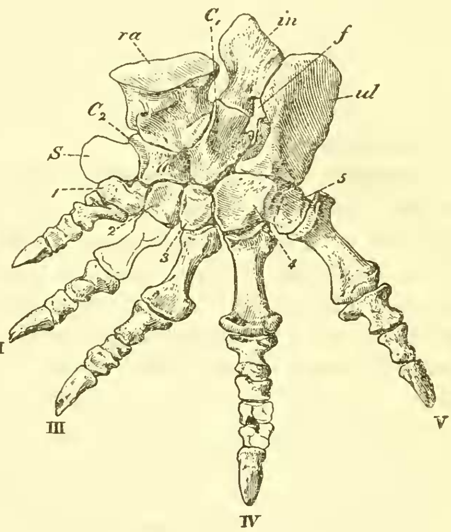

FIG. 8.—LEFT FORE FOOT OF DIMETRODON GIGAS COPE, NO. 8635, U.S.N.M. ONE-THIRD NATURAL SIZE. C_1, C_2, CENTRALE 1 AND 2; *f*, INTRACARPAL FORAMEN; *in*. INTERMEDIUM; *ra*, RADIALE; *S*, SESAMOID; *ul*, ULNARE; 1, 2, 3, 4, AND 5 CARPALE 1 TO 5; I, II, III, IV, V, DIGITS 1 TO 5.

The *radiale* is a stout block-like bone with a flattened proximal end which articulates with the radius. The distal end is wedge-shaped, formed by two nearly equal but oblique articular faces. The outer face meets centrale 2 (C_2), the inner articulates with centrale 1 (C_1). The posterior side of the radiale is channeled by a deep vertical groove running from top to the bottom.

The ulnare is a relatively thin but elongate element, broadly grooved vertically on the posterior side. The subconvex articular proximal end forms the chief articulation of the foot with the ulna. The flattened distal end unites with carpale 4 and 5; most extensively with the former. On the radial side are two distinct articular facets—the upper for the intermedium, the lower unites with centrale 1. The rounded border between these two facets represent the ulnare boundary of the very large intracarpal foramen such as is found in *Sphenodon*. This is considered by Osborn to be a "primitive feature[2] characteristic of other Diapsida."

[1] Williston, S. W. American Permian Vertebrates, 1911, p. 103.
[2] Bull. Amer. Mus. Nat. Hist., vol. 23, p. 269, 1907.

Between the radiale and ulnare is the *intermedium,* which projects well above the proximal ends of those bones, thus interposing itself between and separating the distal ends of the radius and ulna. The inner side of the proximal end articulates with the ulna much as in *Sphenodon.* Above the flat distal end that articulates exclusively with centrale 1 the shaft of the intermedium is constricted, but higher it again expands into a thin plate, being terminated by a bluntly pointed proximal extremity.

On the ulnar side an elongated facet articulates with the ulnare. In the present carpus there is no direct contact between the intermedium and the radiale—a peculiarity which appears to be distinctive of *Dimetrodon* and which differs from all other Permian reptilia. The illustrations of the carpus as published by Case [1] and by Williston [2] certainly give the impression that these bones were in contact in *Dimetrodon incisivus,* but an examination of a carpus of this species shows the same condition prevails as in the specimens here illustrated in figure 8.

Centrale 1 (C_1) has a wedge-shaped proximal end presenting two articular faces; the outer, which is the larger, unites with the radiale; the inner with the intermedium. A slight notch on the ulna side is the contribution of this bone to the boundary of the intracarpal foramen. Below this notch an elongated vertical facet meets the ulnare, while on the opposite side it unites with centrale 2, there being a small foramen at the point where the radiale and the two centrale meet. The distal end is in contact with carpale 3 and 4.

Centrale 2 (C_2) is smaller than C_1. Distally it articulates with carpale 1, 2, and slightly with 3. On the radial side there is a distinct articular facet for the "sesamoid," here restored.

Of the distal row composed of five carpale, carpale 4 is the largest. The first is expanded transversely and presents at its distal extremity a peculiar articulation for metacarpal 1, the external half being on the ventral side, the internal half being on the anterior border. The articular surfaces on carpale 2, 3, 4, and 5, which meet their respective metacarpals are broadly concave from front to back.

Digits.—The metacarpal of the first finger is very small and the finger is very short. The metacarpals gradually lengthen toward the outer side of the foot, reaching their maximum development in the fourth, which, as in *Varanosaurus,* is the longest toe of the foot. The fifth toe is divergent, as clearly indicated by the articular surface of carpale 5.

The digital formula remains to be definitely determined, though there is every reason to believe it to be 2, 3, 4, 5, 3, as here illustrated and as it exists in most primitive reptilian forms.

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[1] Case, E. C. Pelycosauria of North America, Carnegie Institution, Pub. No. 55, 1907, pp. 113, 114, pl. 16, fig. 1.

[2] Williston, S. W. American Permian Vertebrates, 1911, pl. 7, fig. 8.

The proximal row of phalanges, except on digit 1, have widely expanded proximal ends and much narrower distal extremities. The distal articulation is peculiar in having a blunt median projection which is received in a median notch provided for it on the proximal ends of the succeeding phalanges. The toes are terminated by strong, clawed terminal phalanges that were cased in strong claws. The whole structure of the carpus and other bones indicates a strong, flexible foot, such as would be possessed by a carnivorous terrestrial animal.

EXPLANATION OF PLATES.

Plate 70.

Mounted skeleton of *Dimetrodon gigas* Cope. No. 8635, U.S.N.M. Viewed from the left side. About one-twelfth natural size. Mounted by Thomas J. Horne, 1918.

Plate 71.

Skeleton of *Dimetrodon gigas* Cope. No. 8635, U.S.N.M. About one-twelfth natural size. Those parts shown in outline are missing. The sacrum of three vertebrae, pelvis, and interclavicle bones have been introduced from other individuals.

Plate 72.

Fig. 1. Mounted skeleton of *Dimetrodon gigas* Cope. No. 8635, U.S.N.M. Viewed from the rear in order to show the shape of the body cavity and the pose of the fore limbs.

Fig. 2. Mounted skeleton of *Dimetrodon gigas* Cope. No. 8635, U.S.N.M. Viewed diagonally from the left side, in order to show the articulated pectoral girdle.

Plate 73.

Model restoration of *Dimetrodon gigas* based on the mounted skeleton shown in plates 70 and 72. About one-twelfth natural size. Modeled by Charles W. Gilmore, 1918. Inset is *Basiliscus plumifrons* a living lizard, found in Central America, which has a fin-like extension of the neural processes as in *Dimetrodon*. About one-third natural size. After Cope.